

## P. Environmental, natural resources and sustainability

### Estimation method for emission of road transport

Mr. Adam Torok  
Department of Transport Economics  
Budapest University of Technology and Economics  
H-1111 Budapest, Bertalan L. u. 2., Hungary  
e-mail: [atorok@kgazd.bme.hu](mailto:atorok@kgazd.bme.hu)

#### 1. Introduction

Since the beginning of humanity nature gave us a stable base of living and gave almost infinite supply to reserve the biosphere. In early ages humanity caused changes to the environment with limited technology and the rate was infinitesimal compared to the size of the natural environment. Global changes were not detected. In the last two or three hundred years there was an explosion in the development of industrial and technical sector which gave people a multiplied set of tools to encroach nature.

It is a well-known that the growth of GDP induces the growth of motorization. Motorization has developed so dramatically that the air, soil, water pollutions are considerable to the amounts of air, soil and water of Earth. Some of the pollutants affect on local or regional scale while others affect on global scale. There is the natural, non-anthropogeneous greenhouse gas emission developed before the human activity that has been essential for life on Earth. Without it the average world temperature would be -20°C. The CO<sub>2</sub> and temperature data was normalized so that it can be shown in the same graph. (1. figure) [1]

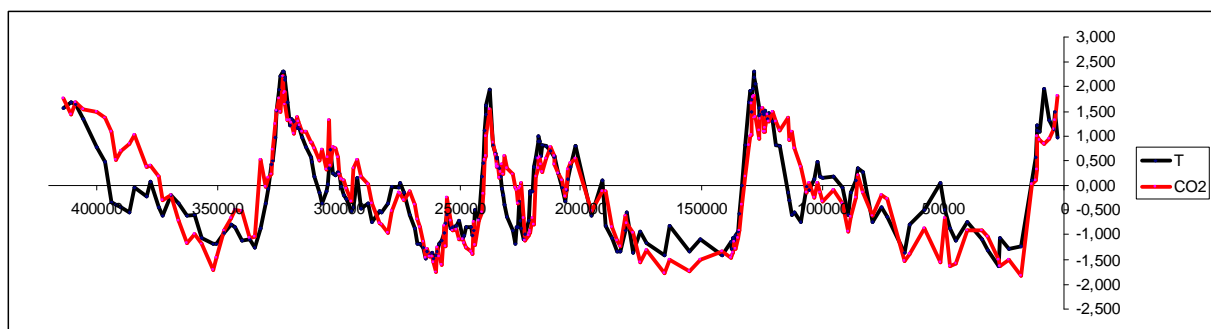
$$u_i = \frac{x_i - \bar{x}}{S}, \text{ where}$$

$u_i$  is the normalized value of temperature or CO<sub>2</sub> concentration without dimension

$x_i$  is the value of temperature [°C] or CO<sub>2</sub> concentration [ppm]<sup>1</sup>

$$\bar{x} \text{ is the average of } x_i \quad \bar{x} = \frac{\sum_{i=1}^n x_i}{n}$$

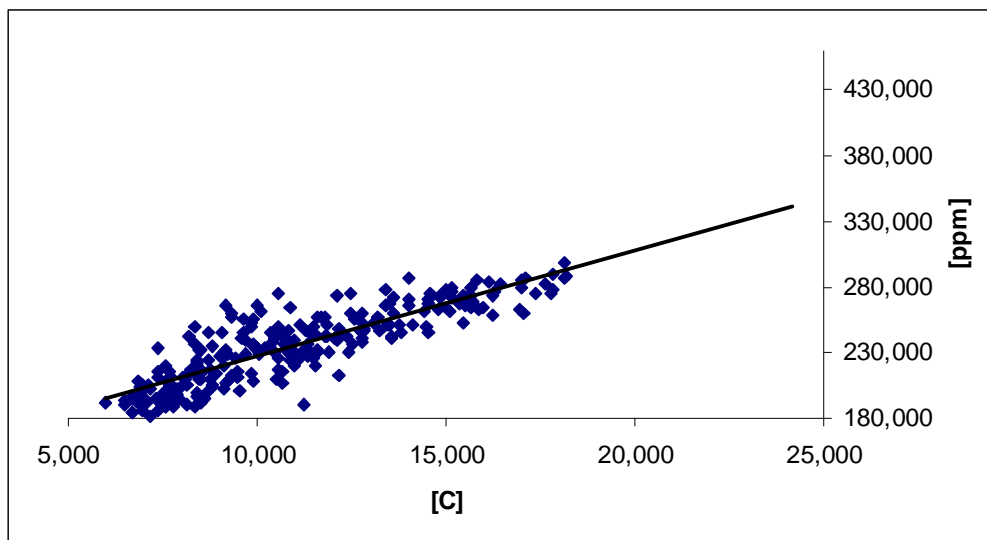
$$\sigma \text{ is the dispersion of } x_i \quad S = \frac{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2}}{n}$$



1. figure Timescale of normalised CO<sub>2</sub> and temperature data before human activity

<sup>1</sup> This is a way of expressing very dilute concentrations of substances. Parts per million or ppm means out of a million. One ppm is equivalent to 1 milligram of something per liter of water (mg/l) or 1 milligram of something per kilogram (mg/kg).

Sustainable development is a development where the pace of technical development, the satiation of increasing supply, raw materials and resources of Earth are poised so that the rate of living and opportunities of the next generations need not to be worse. So global warming caused by the antropogeneous and non-antropogeneous CO<sub>2</sub> can be estimated. The measured data is from the non-antropogenous source, but prediction can be done. To have the best result I have made a Best Fit Analyze. The prediction should be parabolic because when the CO<sub>2</sub> concentration grows smog or cloud arises that blocks sunlight from Earth, the only source of heat. The growing CO<sub>2</sub> concentration part of the parabola can be approximated by linear trend. (2. figure)



2. figure Estimation of average temperature increase caused by increasing CO<sub>2</sub> emission

The other part of the emissions caused by the motorization is local or regional. Theoretically one solution could be to stop motorised transportation. Stopping motorised transport leads to stopping pollution caused by the transport says the Clean Air Action Group.

Transportation cannot be replaced because it is the part of the production chain. Societies are horizontally and vertically differential. People live in different places and do different things for living. The manpower, the stock, the semi-finished and finished products must be transported. The importance of the transportation sector is indicated by the sector production which is 10% of the GDP of the European Union and more than 10 million people are working in this sector. One of the most emphasized goals of the transport policy of the European Union is sustainable mobility. For this reason transportation systems must be developed and standardized, the effectiveness of transportation service must be increased, while the environmental pollution must be decreased or prevented. This is a task for engineers and operators as well.

The vehicles used nowadays are polluting. Most of them are converting fossils to mechanical energy and during the conversion 40% of the fossil energy is converted to heat energy that is useless, waste thereby heating our environment.

## 2. Importance of environmental pollution in costing

People who would like to make rational decisions, make an optimization, choosing the maximum utility and benefit. Theoretically, all benefits and costs should be accounted in the analysis. In practice though, many effects are left out (listed below) either due to difficulties of estimating a trustworthy monetary value, or difficulties of quantifying the effects or because the effects are considered to be of minor importance.

- Passenger transport time savings,
- User charges and revenues,
- Vehicle operating costs,
- Safety,
- Noise,
- Air pollution - local/regional,
- Climate change.

The CO<sub>2</sub> emission caused by the burning of fossils can be decreased by decreasing the fuel consumption or by changing to another driving method that converts energy without burning fossils. Other transportation emitted pollutants can be decreased or prevented by improving our fossil driven internal combustion engines or changing the driving method to alternative energy source. There are several keys to cleaner transportation. Hybrid vehicles, methane, fuel cells, electric vehicles but the problem is that the performance of these vehicles are not good enough compared to the fossils driven vehicles, because the CO<sub>2</sub> production has just shifted to the energy production sector from the transport section. Solution can be H<sub>2</sub>, if we can produce H<sub>2</sub> without producing CO<sub>2</sub>.

From the side of policy makers another solution can be to press the people to have “green” decisions with making “green” policies. Traffic management systems, low emission zones as the element of arranging a city or the better land-use planning can also decrease the demand of mobility. Externalities should be internalised and indicated in the cost of transportation according to the EU guideline „Users should pay the bill”. Some of the external costs can simply be added to the average costs but some of them need a totally different aspect and pricing method, the marginal costs based pricing method. The more realistic pricing method we want, the more externalities should be included to the marginal costs based pricing method. Some of them can be calculated and monetized, some of them can be estimated, and some of them cannot be expressed in monetary terms.

## 3. Environmental impacts

The environmental external effects of transport cover a wide range of different impacts, including for example noise, local/regional air pollution and climate change. Transport infrastructure projects often affect local and regional air pollution. Some of the countries take this into account in some forms in the project appraisals. There is no consensus on which elements should be included in the monetary valuation. Most of countries which include *air pollution - local/regional* with a money value in the project appraisal include PM, NO<sub>x</sub>, SO<sub>2</sub>, HC and CO. Only *Pb* is not included in the appraisal in most of the countries. The category *other* includes carcinogenic species (Germany) and polycyclic aromatic hydrocarbons (Hungary and Germany). The base of the money value for *air pollution - local/regional* is the *impact pathway approach*. Lot of different approaches are used. Some countries use more than one approach for

estimating the money value. There is no consensus on which effects to include in the money value for *air pollution - local/regional*. All countries, which include the effect on air pollution with a money value and for which the information is available include *Human health - production loss from sickness and increased mortality*.

The amounts of emissions from road traffic have enough impact on the environment to be taken seriously. Many traffic emissions come only through the exhaust pipe. These are for example NO<sub>x</sub> and CO. They are easy to measure, in the sense that they can be sampled from the exhaust pipe and measured on-line in real traffic. Other techniques are to collect samples for later analysis or to measure the emissions while driving on a dynamometer. Even though the sampling and data collection seems to be easy, this will be for practical reasons only possible for small sets of cars and some traffic conditions and cannot easily be rescaled for a whole vehicle fleet or every possible driving situation. Other emissions may be evaporative; the major sources are hot soak losses and evaporation. Hot soak losses are caused by the heating of the fuel system when a hot engine is turned off and the system is no longer cooled by flowing fuel. Evaporation comes from the ventilation of the fuel tank when the temperature varies from day to night. The evaporative losses are harder to measure because there is no easy way to sample the evaporation. Different approaches have been tried for developing a model for evaporation emissions, and today there are competing models that giving rather different results. Some emissions like heavy metals can be estimated by an indirect method where the metal content in the fuel is determined separately and multiplied by the fuel consumption. Emissions from road traffic are good examples of a complex system with an output that cannot be completely measured. It is natural to analyze the emissions from a sample of vehicles under different driving conditions and other conditions (temperature, fuel content, road gradients, etc.) and to try to create an emission model for the traffic. Depending on what data are collected about the traffic the model may be more or less detailed and complex. Traffic data are not collected in the same way and with the same level of detail in every country and this is a problem if a model is meant to be used for calculations in many countries or for comparisons between them.

#### 4. Estimation method

The EURO standards based on the ECE-R15 driving cycle: [3] Each vehicle category has its own limits. The vehicle flow (G) can be divided into groups by EURO standards ( $\alpha_i$ ) and vehicle categories ( $\beta_i$ ) with its pollutant limits. Being aware of the vehicle numbers in each category multiplied with the limit they can be summarised. Now the pollutants can be calculated from the given vehicle flow and the given distance. [4]

$$\underline{G} = \begin{bmatrix} g_{11} & \mathbf{L} & g_{i1} \\ \mathbf{M} & \mathbf{O} & \mathbf{M} \\ g_{1j} & \mathbf{L} & g_{ij} \end{bmatrix}, \text{ where:}$$

$$\sum_{i=1}^n g_{ij} = a_j \quad j=1, \dots, m \text{ emission of vehicle of the EURO } j \text{ standard}$$

$$\sum_{j=1}^m g_{ij} = b_i \quad i=1, \dots, n \quad \begin{cases} M_i \cdot & | i: 1..3 \\ N_{i-3} \cdot & | i: 4..6 \end{cases} \text{ vehicle categories}$$

$$\sum_{i=1}^n \sum_{j=1}^m g_{ij} = \sum_{j=1}^m a_j = \sum_{i=1}^n b_i \text{ sum of the domestic vehicles}$$

## **Summary**

Nowadays the motorised vehicles are driven by internal combustion engines. These engines pollute the environment. Growing traffic causes increasing environmental pollution that has global, regional and local effect as well.

The only solution to prevent pollution while the freedom of mobility is not bounded is to switch to an alternative source of energy that can be safely stored, used, available and the procedure of this energy is also clean.

There is a justifiable demand by the society to moderate the environmental impacts caused by road transportation. Managing traffic is based on the costs. The external costs should be monetized to have a clear scope of utility of transportation. The paper presented a model of the emission caused by the vehicle flow. The model grouped the vehicles by categories and by the emission of the vehicle's EURO standards. With this classification the estimation can be done by the described process.

## **References:**

[1] <http://www.nature.com/nature/journal/v399/n6735/extref/399429a0.co2nat.txt>

[2] MC-ICAM Deliverables 4, 5, 6 - EU Commission DG TREN, 2003

[3] Vehicle Emission Standards and Inspection and Maintenance - Recent European Union (EU) emissions standards [www.unece.org](http://www.unece.org)

[4] Calculation of the emission surplus of the incoming vehicles in the traffic flow consideration of the international limits (in Hungarian) - Scientific Review of Transport – 2005/9 Adam Torok, Mate Zoldy